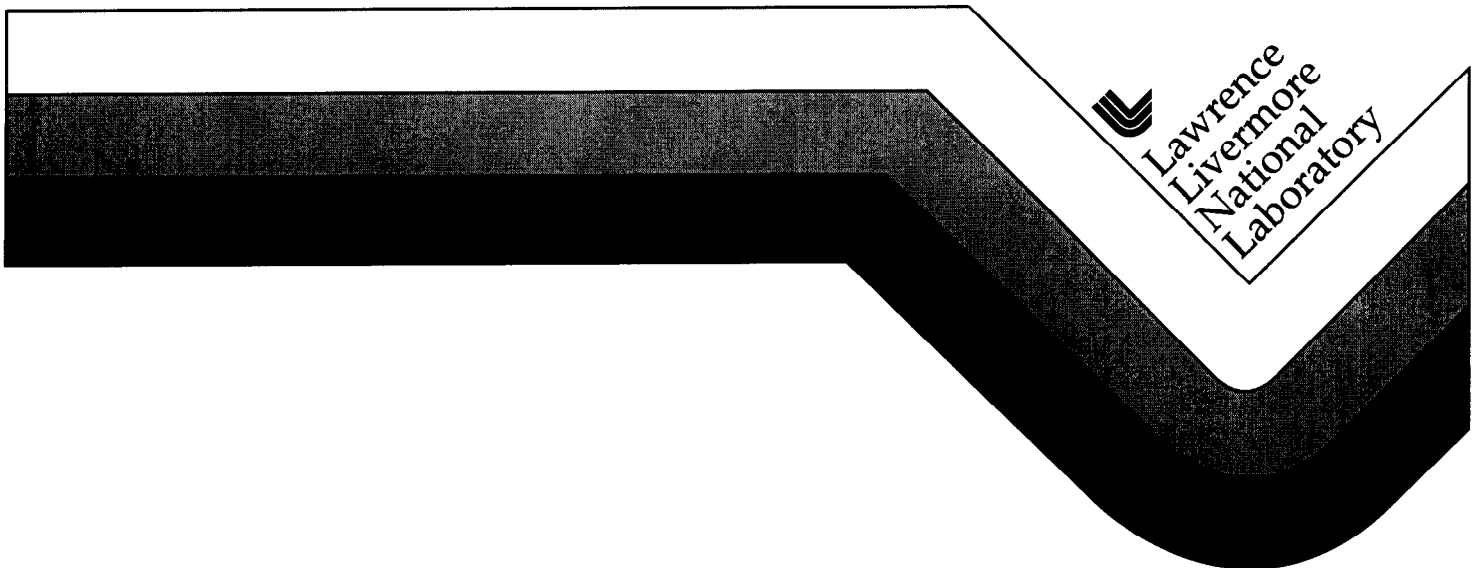


Exposure Standard for Pulsed Magnetic Fields

Gordon Miller

May 1999



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Lawrence Livermore National Laboratory

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Preface

The Exposure Standard for Pulsed Magnetic Fields is one of several local Lawrence Livermore National Laboratory (LLNL) environmental, safety, and health standards that was prepared during the Work Smart Standards Closure Process to address areas not adequately covered by Department of Energy (DOE) orders or national consensus standards. The original version was approved on March 16, 1999. Questions or comments about this standard should be addressed to the Technical Support and Policy Development Division in the Hazards Control Department.

Lawrence Livermore National Laboratory
Exposure Standard for Pulsed Magnetic Fields

1.0 Purpose

This standard provides guidance for employees who work with peak magnetic fields and specifies how much they can be exposed to where the graph of the field strength vs. time (waveform) is a square wave, sinusoidal, and a short train of sinusoidally varying waves if the duration of the pulse or pulse train is below 10 ms.

There is no standard for pulsed magnetic fields promulgated by a standards-setting organization; therefore, LLNL prepared this standard because the Laboratory has experimenters who use an extremely wide variety of wavelengths and waveforms. This standard adopts guidance from a reference that was expressly developed for incorporation into the next edition of the Institute of Electrical and Electronic Engineers/American National Standards Institute (IEEE/ANSI) Standard C95.1, "American National Standard Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz." The C95.1 committee has had this guidance since 1995 and has not made adverse comment so it is very likely that it will be part of the next revision of Standard C95.1; therefore, this standard should be viewed as an amendment to IEEE C95.1-1991. The LLNL *Environment, Safety & Health (ES&H) Manual*, Volume 2, Supplement 26.12 (Nonionizing Radiation and Fields) references IEEE C95.1-1991 and the other standards that give direction applicable to other nonionizing radiation exposure scenarios including:

- Pulsed electric fields
- Continuous wave electric fields
- Continuous wave magnetic fields
- Pulsed or continuous wave microwave radiation

The national standards referenced in Supplement 26.12 are those cited in the LLNL Work Smart Standards set.

2.0 Exposure Standard

Peak magnetic fields shall not exceed the limits shown in Figure 1:

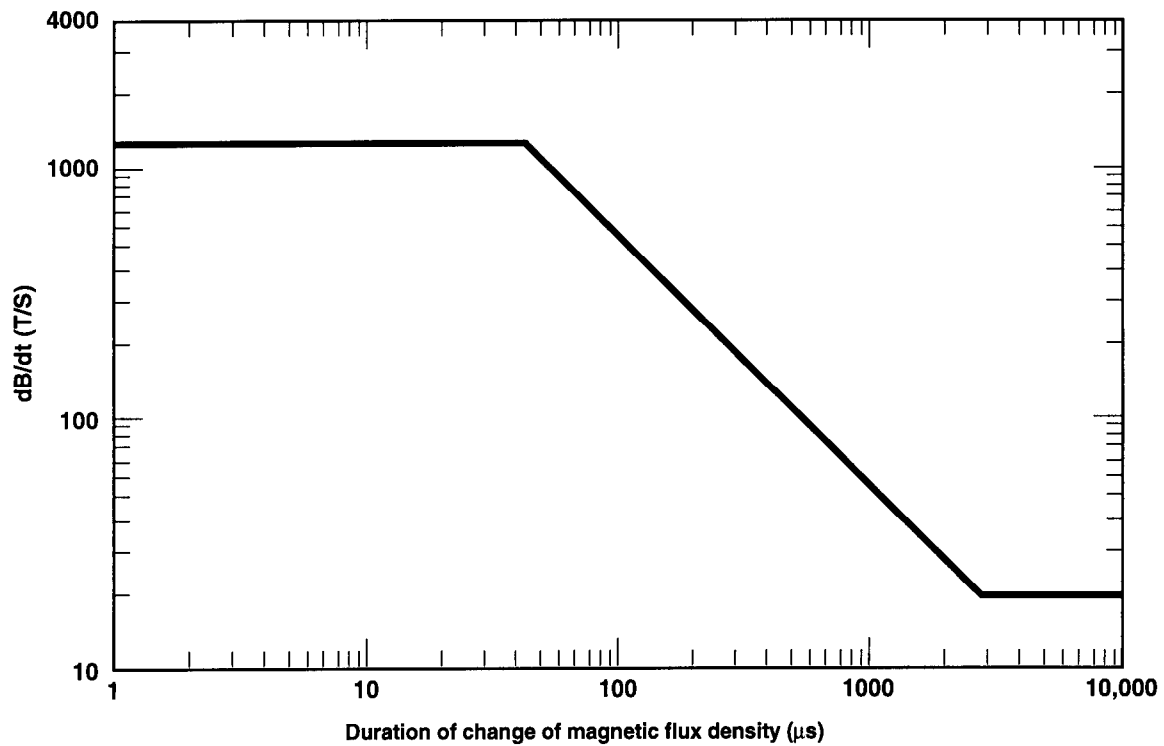
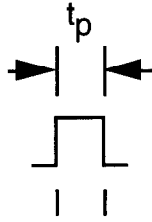


Figure 1. Permissible rates of change of a pulsed magnetic field.

NOTE: The following waveforms are used to determine the rate of change of the pulsed magnetic field:

- For square waveforms: Duration = t_p .
- For single sinusoidal waveform pulses: Duration = duration of half cycle.
- For pulse containing multiple sine waves: Frequency = duration of a half cycle of the sine waves.

These relationships are depicted below:



Square wave



Single sinusoid



Multiple sinusoid

For other waveforms, t_p = the time interval between the 10% and 90% rise times of the waveform.

The radiofrequency limits in IEEE C95.1-1991 should be used for frequencies >200 kHz. The break in the middle of Figure 1 occurs at a pulse duration of 123 μ sec, while the break on the left occurs at a pulse duration of 2.5 μ sec. The right side of the graph shows a pulse duration of 10,000 μ secs. If the frequency is defined as $1/(2 t_p)$, the break in the center occurs at 4071 Hz, the break on the left occurs at 200 kHz, and the right side of the graph is at 50 Hz.

3.0 References

Institute of Electrical and Electronic Engineers, "American National Standard Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz," C95.1-1991 (1992).

Reilly, J. Patrick, "Maximum Electromagnetic Field Limits Based on Peripheral Nerve Stimulation: Application to IEEE/ANSI C95.1 Electromagnetic Field Standards." *IEEE Transactions on Biomedical Engineering*, **45**(1), 137–141 (1998).